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STACK CONTAMINATION - 200 AREAS

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DATE 9/6/67
For The Atomic Energy Commission
-H. R. Conner
Chief, Declassification Branch

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200-AREA STACK CONTAMINATION

INTERIM REPORT - OCTOBER 12, 1948 - JANUARY 24, 1949

SUMMARY

This report summarizes the status, technical findings, and comments and suggestions since the writer's last Interim Report, dated October 11, 1948, was issued.

Sand filters that were installed on the 221 Building ventilation exhaust air went into operation on October 15, 1948 in West Area and on October 30, 1948 in East Area. The collection efficiency of these units has been measured as 99.5% in West Area and 99.9% in East Area. The air handled in West and East Areas is believed to be 22,000 cu.ft./min. and 27,000 cu.ft./min., respectively, although this is not a firmly established value.

Despite the high collection efficiency of the sand filters, the stack effluent contamination has only been reduced by a factor of about 10. This apparent recontamination is believed to originate primarily from the dissolver off-gases which are not now passed through the sand filter and which are mixed with the gases from the sand filter at the base of the stack. This problem was considered in a separate memorandum dated January 18, 1949 (HDC 969).

Now that sand filters are in successful operation, it is suggested that consideration be given to commercial equipment such as the Hersey filter or Cottrell precipitator in anticipation of the time when the existing sand filters may require replacement or when other large installations are required for this type of service.

Test results on Fiberglas have indicated marked advantages over sand. It is anticipated that future installations will involve graded layers of Fiberglas rather than sand. Consideration should be given to other fine fibers, such as rock wool, on the basis of overall installation economics.

Full Scale Sand Filters

Since start-up of the large scale units in the 200 East and West Areas, daily measurements have been made on the performance of the sand filters and on the stack effluent quality by the Technical and Operating Division. The results of these tests are given in Tables IA, IB, IIA, and IIB.

Collection Efficiency: The sand filter efficiency was determined by sampling and main ventilation gases upstream and downstream from the

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sand filter and passing the samples through C.W.S. Type 6 filter papers, which are then monitored in various ways and also analyzed for activity. The averages of all these various methods of evaluating the test filters are given in Table VII. This method, however, will not give a reliable average efficiency since each value which is in error will reflect in the average. The direction of the error will normally be to indicate a low collection efficiency, since when dealing with such high efficiencies, it takes only a few low erroneous measurements to pull down the average considerably. A better method is to consider all the evaluations of a single filter paper to arrive at a "weighted" average for that paper, leaving out values which do not check the other values or which are not considered reliable as judged by specific circumstances of the measurement. The average of these "weighted" average values should give a reasonably reliable measure of performance.

Such a procedure indicated a collection efficiency of 99.5% and 99.9% for West and East Areas, respectively. These values are somewhat (0.3 to 0.5%) lower than anticipated on the basis of previous test data but still within the accuracy that can be expected. The East Area sand filter differs from the West Area filter in that it contains 3 ft. of Type G sand whereas West Area contains only 2 ft. Since both filters are the same size, 46 ft. by 108 ft. inside dimensions (although air inlet and outlet details differ), the superficial gas velocity in East Area is about 5.4 ft./min. (see paragraphs below) whereas it is only about 4.4 ft./min. in West Area. Allowing for these differences, the relative performance of East and West Areas agrees well with what would be predicted from previous test data.

Air Handling Capacity: Pressure differential measurements were made by the Technical Division on both systems as recorded in Table V. On the basis of fan performance curves, making due allowance for fan speed, these measurements indicated an air flow of 32,000 and 27,000 cu.ft./min. in East and West Areas, respectively. An analysis of the differential measurements, however, indicates that this flow is considerably too high to be consistent with the differentials. It is the writer's estimate that the actual gas handled in these systems is some 5,000 cu.ft./min. less than indicated by the fan performance curves. This would mean that the fan performance curves are in error to the extent of being 10% high on indicated static pressure. Considering past experience with fan performance curves* and considering the idealized conditions under which they are obtained, such a 10% divergence is entirely reasonable.

Bed Compression: On the basis of the air flow estimated from the fan performance curves, the pressure drop through the fine sand in both Areas is considerably less than would be expected for an uncompressed bed on the basis of previous experimental work. This is another indication that the fan performance curves are in error.

*It should be pointed out here that static pressure as defined in performance curves is not simply the difference in pressure measured across the fan. It is defined as the difference in pressure directly across the fan inlet and outlet ports (without intervening transition pieces) minus the velocity pressure at the fan inlet. Further details on this point can be obtained from "Fan Engineering", a handbook put out by Buffalo Forge.

Various tests indicated that compression could result in a potential increase in pressure drop of about 70 to 100%. In the absence of reliable air-flow values, no conclusions can be reached as to the actual amount of compression that has taken place during placement of the sand. On the basis of the information available, however, it would appear that the increase in pressure drop due to compression was not more than about 20%. It also appears that there was more compression in the East Area bed than in the West Area sand bed unless there is appreciably more than 5,000 cu.ft./min. difference in the air flows in the two systems.

Recontamination: Despite the high collection efficiency of the sand filter, the concentration of active particles at the outlet of the stack has only been reduced by a factor of about 10. This apparent recontamination may be due to (1) recontamination resulting from previous accumulations on the stack, (2) by-passing around the sand filter, or (3) contamination from the dissolver off-gases which are now bled into the base of the stack and do not pass through the sand filter.

Special tests (Table IB) have been made by the Technical Division on the East Area system. Runs made while the dissolvers were not in operation indicated a 90% reduction in the apparent recontamination. Runs made using an air jet in place of a steam jet to motivate the dissolver off-gases showed little effect. It is felt, therefore, that most of the apparent recontamination comes directly from the dissolver-off-gases and that there is no effect of steam introduction either in the way of "fixing" vapor as particles or of steam condensate becoming contaminated in the stack.

The problem of controlling contamination from the dissolver off-gases has been considered in detail in a letter dated January 18, 1949 (C. E. Lapple to V. W. Wood, HDC No. 969). Once the dissolver off-gas contamination is taken care of, however, there is still a possibility of some other source of recontamination, either from the previous contamination of the stack or by-passing of the sand filter through leaks in the duct work or through the water seal. The latter are felt to be unlikely possibilities. It is not now possible to say what the stack contamination may contribute since any such effect is entirely masked at this time by the predominant effect of the dissolver off-gases.

Recommendations and Suggestions: If it is desired to obtain more

reliable information on the air flow in the two systems, it is suggested that direct air flow measurements be made, although it is not felt that this is a very important matter at this point. Two methods suggested are:

(1) Pitot Traverse: While this can be done with simple equipment, the duct work, with its internal ribs, is not too well suited for such a measurement and the pitot differentials obtained will be small, on the order of 0.03 to 0.06 in water.

(2) Dilution Method: A contaminant which is not normally present in the system (such as; a radioactive tracer, ammonia, sulfur dioxide, etc.) can be introduced at a known rate into the duct work after the sand filter. The concentration of this contaminant in the air leaving the first or second fan can then be determined to obtain a direct measurement of the air flow in the system in terms of the degree of dilution and the rate of introduction of the contaminant.

It is also suggested that once every two or three months, a series of incremental pressure drop measurements be made on the systems, similar to those indicated in Table V, in order that we may have adequate warnings of any plugging tendencies. It should be emphasized that such readings should be taken by direct differential readings between successive points in the system. Static pressure measurements at each point are not accurate enough to permit any reliable analysis of the data to be made since we would be dealing with small differences of relatively large readings, each of which is subject to appreciable fluctuation.

While the filters are operating satisfactorily now, we must face the fact that they will have to be replaced at some time in the future. On the basis of data obtained on the full scale units to date, it is felt that the life of the units should be at least 2 to 3 years. How much more than that, cannot be predicted from these data. We now have an opportunity to consider more economical units as a replacement for the sand filters when such becomes necessary or as an alternate for future new installations in a similar type of service. It is consequently suggested that serious consideration be given to the design, cost estimated, and possibly the actual installation of a Hersey filter or a Cottrell in parallel with the sand filter. If the cost estimate indicates a large savings over a sand filter, the installation of a unit in parallel with the sand filter would make it possible to determine their practicability from a maintenance standpoint. If they fail, the sand filters are still available to take the load. The sand filter was originally recommended as a unit which would probably do the job with a minimum of maintenance and which could be installed in a minimum of time. It is not necessarily the most economical unit for the job. Available commercial units, such as the Hersey filter and Cottrell precipitator, were discarded as possibilities because of the time element for procurement and because of

doubts concerning the possible maintenance. Perhaps maintenance will not be as serious as potentially envisioned. This can only be determined by an actual installation, which is not possible, since it will not create any hazard of a plant shutdown if the unit should fail.

Sand Filter Test Program

Sand Filters: Tests have been completed on the evaluation of sand as a filter medium. The results obtained in this period are given in Table III and summarized in Table VIII. Screen analyses of the sands used are given in Table VI. These data supplement those given in the previous Interim Report. The results check the general conclusions and correlations previously obtained. The results on Ottawa 20-30 mesh sand line up particularly well with previous results. The results for Hanford 20-40 mesh sand, however, seem to be on the low side insofar as collection efficiency is concerned and on the high side on pressure drop as compared to previous measurements on this sand. The data are also conflicting and confusing amongst themselves. On the average the collection efficiency is about the same as that of the Ottawa 20-30 mesh sand for the 3 and 4 foot depths although repeated tests have previously shown it to be considerably better. No explanation is offered.

Fiberglas Filters: No. 55 Fiberglas packing was tested in a manner similar to the sand. In this case the Fiberglas was mounted directly on an 8-mesh screen, with no additional layers of coarse sand. Tests have been completed on arrangements in which the Fiberglas was packed to a density of 6.0 lb./cu.ft. The complete results of these tests are given in Table IV and summarized in Table IX. Tests are currently in progress on Fiberglas packed to a 3.0 lb./cu.ft. density. Results available to date are summarized in Table IX.

It is apparent from these results, that Fiberglas is capable of giving considerably higher collection efficiency and lower pressure drop for a given specified velocity than the various sands tested. Stated in another way, the use of Fiberglas should result in a more economical installation for a given capacity and permit a longer filter life.

In the previous interim report, the experimental collection efficiency data have been correlated in terms of a transfer unit concept:

$$\eta = 1 - e^{-N_t}$$

where η = fractional collection efficiency, dimensionless
e = natural logarithmic base, 2.718.....
 N_t = number of transfer units, dimensionless

The sand data indicated that N_t could be approximately related to the operating conditions by:

$$N_t = K L^{1/2} V^{1/3} D^{4/3}$$

where L = depth of bed, feet.
 V = superficial velocity, ft./min.
 D = average sand grain diameter, inc.
 K = proportionality factor, min. $1/3$ /ft. $7/6$

the value K being a function of the sand grain shape and degree of packing or voidage for a given aerosol size and size distribution.

The data for Fiberglas (D = 0.00055 in.) have been found to correlate in the same way within the limits of precision of the data. The value of K so obtained averaged 4.8×10^{-4} . The following table compares the value of K thus far obtained:

Type of Sand or Fiber	Approximate Bed Voidage (fractional)	K
Hanford	0.4	0.053
A.G.S. Flint	0.4	0.045
Rounded Sand Grains (Ottawa, Eau Claire, Monterey)	0.4	0.035
No. 55 Fiberglas (6-lb. packing)	0.96	0.00048
No. 55 Fiberglas (3-lb. packing)	0.98	0.00012 - 0.00026

By comparing these values of K, it can be shown that the effect of voidage can be approximated by the function $(1-\epsilon)/\epsilon^2$ where ϵ is the fractional voidage of the bed. In other words K is approximately proportional to the grouping $(1-\epsilon)/\epsilon^2$. This is by no means a rigorous relationship that has been demonstrated but simply an observation of a relationship which appears to fit the facts. There is also some theoretical justification for this grouping considering analogies with equations for the effect of voidage on flow and pressure drop. For the time being, however, this relationship should be treated merely as a guide in estimating the order of magnitude effect of changing voidage. The results on 3-lb. Fiberglas packing indicate a considerably lower value of K for the 1-ft. depth of packing than for the 2-ft. depth. This may be due to channelling due to slight irregularities in packing at such a low depth. However, further data are required to clarify the results on the 3-lb packing.

The pressure drop through Fiberglas packing can be represented by:

$$\Delta p = K_p V L$$

where Δp = pressure drop, in. water
Kp = proportionality constant, (in. water) / (ft.) (ft./min.)
V = superficial velocity, ft./min.
L = depth of fiber bed, ft.

The average value of Kp obtained in the tests summarized in Table IX is 0.07 for the 6-lb. packing and 0.016 for the 3-lb. packing. This variation in Kp is approximately proportional to the grouping $(1 - \frac{1}{3})^2$ which is the theoretical (Carman-Kozeny) variation to be expected as the result of varying voidage.

Recommendations for Future Test Program

1. Completion of tests on 3-lb. Fiberglas packing, covering depths of 1, 2, and 4 ft. and a superficial velocity range of 2 to 15 ft./min. At the end of these tests it is suggested that the filter connections be revised to permit gas down-flow through the filter, and conduct tests covering a superficial velocity range of 2 to 50 ft./min. There are some reports in the C.W.S. literature to the effect that high humidities result in a decrease in efficiency of Fiberglas filters. It is suggested that this be evaluated by making additional runs in which steam is injected into the inlet gases at a rate of 1/4 (lb./hr.) / (cu.ft./min.) of air handled, which is about three times the amount required for saturation. The steam should be injected at a point at least 15 diameters ahead of the filter inlet, preferably ahead of a bend. It is also suggested that such runs be made with down-flow as well as up-flow through the Fiberglas.
2. Tests on other Fiberglas grades may be indicated at a later date, following the writer's proposed visit to Owens-Corning Fiberglas Corp. It is anticipated that improved filter performance is possible by going to beds of smaller fiber diameter and greater voidage. It is also expected that the fiber cost in that case will be disproportionately higher and will not justify its use except for a thin cleanup layer.
3. There is some possibility of matting-down of the Fiberglas upon becoming wet. The fiber as received is coated with a binder to prevent fiber segregation during handling. This binder is oily in nature and prevents wetting of the fiber with water. After being in a place for a long period of time, this binder will undoubtedly deteriorate and wetting of the fiber will be possible. It is suggested, therefore, that qualitative tests be run to determine the wetting and matting properties of the glass wool after first removing the binder with a solvent such as acetone.
4. Certain reports in the C.W.S. literature indicate that rock wool has been successfully used in filters and is available at considerably less cost than glass wool. It is suggested that Johns-Manville be contacted to obtain descriptive information and approximate costs on

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rock wool or similar fibers in the range of 1- to 30- microns fiber diameter. On the basis of this information it can be determined whether sufficient justification over Fiberglas exists to conduct tests on rock wool. The possibility of matting-down of the rock wool on becoming wet must also be considered.

5. It is suggested, in connection with both the 200-and 300-Area contamination problems, that wool felt of the type used on the Hersey filter be procured and tested in series with C.W.S. Filters to evaluate its performance in the way of collection efficiency and pressure drop, covering a superficial velocity range of 10 to 50 ft./min. In placing such a cloth in a flange, care should be exercised to avoid leakage of atmospheric air through the outer edge of the wool. It is suggested that a triple gasket be used, one on either side of the cloth to avoid by-passing of process gases around the cloth, and one beyond the outer edge of the cloth to avoid in-leakage of atmospheric air. The filter cloth can probably be secured either from Pulverizing Machinery Company in Summit, N.J. or the Day Co. It is best to contact both vendors to be sure they use the same fabric.

In view of the 300 Area problem, it is suggested that tests on this fabric be given a high priority and procurements of the fabric be expedited. One square yard of the material should be ample and two square feet sufficient. These can probably be obtained as a sample.

6. It is suggested that separate permeability tests be run on all filter materials simultaneously with the collection efficiency tests.

7. As an alternate to a full scale installation in 200 Area and in anticipation of the 300 Area installation, a small scale Hersey filter unit might be considered for test in 200 Area in order to determine maintenance and operating characteristics which cannot be determined from the fabric alone. A small unit can be obtained from Pulverizing Machinery Co. I believe the smallest unit has about 10 sq. ft. filter surface which would correspond to a capacity of 100 to 300 cu.ft./min. The advisability of such a test installation can best be determined after evaluation of the Hersey Wool felt as discussed in Item 5 above.

General

The writer is planning to stop off at Owens-Corning Fiberglas Corp. in Newark, Ohio for the purpose of determining what is available in the way of types and grades of Fiberglas and the approximate cost of each. The objective of this information is to (1) clarify the economic picture on Fiberglas for this type of application, (2) to arrive at specifications for Fiberglas packing arrangements, and (3) to determine what, if any, further test work is required on evaluation of other grades of Fiberglas. The individual to be contacted at Owens-Corning is Mr. Dale Kleist.

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On the basis of the results obtained with Fiberglas, it appears that any future installations of filters would involve Fiberglas rather than sand. The size of filter to be used for any specific application will depend specifically on the dust loading involved in terms of anticipated filter life. It is recommended that any Fiberglas filters be made up of graded layers of successively finer fiber for the sake of prolonged filter life. The writer will submit a suggested gradation following the visit to Owens-Corning. The depth of fine fiber to be used will depend on the collection efficiency desired. While the pressure drop through the Fiberglas packing is considerably lower than through sand at a given superficial velocity, it should be pointed out that the rate of build-up of pressure drop due to solids accumulation is expected to increase more rapidly on a percentage basis referred to the initial pressure drop although it should be less on an absolute pressure drop basis. Consequently, it is suggested that any designs allow for an ultimate pressure drop which is high on a percentage basis in order to realize added filter life. For example, if the filter is designed so that the initial pressure drops through the fine Fiberglas is about 1 in. water, an allowance for an ultimate pressure drop of 4 to 5 in. water should be made.

/s/ C. E. Rapple

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TABLE V

Pressure Measurements on East and West Area Sand Filters

(Made during Period 1/13 - 1/17/49)

	<u>East Area (B)</u>	<u>West Area (T)</u>
Pressure Differentials, in. water		
Atmosphere to sand filter inlet	2.15	1.15 - 1.20
Sand filter entrance to bottom of G layer	0.45 - 0.50	0.60
Bottom G layer to plenum chamber	6.7 - 6.8	3.30 - 3.35
Plenum chamber to sand filter outlet	0.1	0.1
Sand filter outlet to upstream fan inlet	0.65	0.40
Across upstream fan (#2 fan)**	4.75	6.08 - 6.18
Between fans**	0.25 - 0.30*	
Across downstream fan (#1 fan)	5.15	
Sand filter inlet to sand filter outlet		
Measured	7.3 - 7.4	4.15 - 4.2
Calculated from other measurements	7.25 - 7.40	4.00 - 4.05
Atmosphere to downstream of upstream fan		
Measured	5.30	---
Calculated from other measurements	5.35 - 5.45	0.38
Atmosphere to upstream of downstream fan		
Measured	5.15*	
Calculated from other measurements	5.10 - 5.15*	
Atmosphere to downstream fan discharge (calc)	0.0*	
Fan Speeds, rev./min.		
Upstream fan (nearest sand filter) (#2)	889	945
Downstream fan (nearest stack) (#1)	Not Measured	
Temp. °C		
Sand filter inlet (therm. strapped to duct)	11	---
Sand filter outlet (thermocouple)	---	14
Air Flow cu.ft./min. (estimated from fan performance)	32,000***	27,000***

* Reading between upstream and downstream fan is in reverse direction of what it should be, being higher on the downstream side of the upstream fan. This may be accounted for by the fact that the upstream tap on #1 fan is on the outside of the 90° bend connecting #1 and #2 fans.

** Taps across fans are located practically at entrance and exit of fans. The fan inlet is 45-3/8 in. i.d. (circular) and the exit is 34-3/8 in. x 47-3/4 in. i.d. (rectangular).

*** Considering pressure differentials measured in system it is estimated that the actual air flow is 4000 to 5000 cu.ft./min. less than these values. This would be compatible with the fan performance curves if the latter were in error to the extent of being 10% high.

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TABLE VI

Screen Analyses of Sands for Which
Test Results are Given in Table VIII**

Screen Analysis No.				32	33	34	35	
Type Sand		<u>Ottawa 20-30 mesh</u>		<u>Hanford 20-40 mesh</u>				
Sand Filter Portion		3rd ft.	4th ft.	1st ft.	2nd ft.	3rd ft.	4th ft.	
Sand Filter Runs No.		<u>101-104</u>	<u>105-109</u>	<u>110-113</u>	<u>114-117</u>	<u>118-120</u>	<u>121-123</u>	
Cumulative % Larger Than								
	<u>Mesh</u>	<u>Aperture, in.</u>						
	20 US	0.0331	0.4	0.2	0.3	1.3	1.4	0.7
	30 US	0.0232	98.3	96.0	19.6	22.1	25.6	---
	40 US	0.0165	99.9	100.0	64.3	65.7	67.8	80.5
	50 US	0.0117	----	----	----	----	----	----
	60 T	0.0097	100.0	100.0	96.6	96.5	94.0	99.3
	80 US	0.0070	----	----	99.6	99.1	97.7	99.9
	100 US	0.0059	100.0	----	99.9	99.5	99.7	100.0
	200 T	0.0029	----	----	99.9	----	----	100.0
Average Particle Dia- meter,* in.			0.028	0.027	0.019	0.019	0.019	0.021

* Corresponding to 50% cumulative - weight size.

** Other screen analyses referred to in Table VIII are given in Table II of Interim Report for August 2 - October 11, 1948, dated October 11, 1948.

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TABLE VII

Summary of Large Scale Sand Filter Collection
Efficiency Measurements Reported in Tables I and II

	East Area (Runs 1 - 50)		West Area (Runs 1 - 50)	
	Average of All Measure- ments	Average, leaving out "greater than" values	Average of All Measure- ments	Average, leav- ing out "grea- ter than" val.
<u>Basis*</u>				
Cutie Pie				
Beta / Gamma	>99.90(40)	99.89(31)	>99.42(50)	99.41(42)
Gamma	>99.48(40)	99.59(7)	{>99.00(49)**	99.13(20)
			{>98.35(50)	
Lab. Cutie Pie $\beta + \gamma$	>99.85(32)	99.80(26)	{>99.26(42)**	{99.29(39)**
			{>98.96(43)	{98.96(40)
Lab. Analysis				
Beta	99.81(31)		{99.49(39)**	
Gamma			{99.23(42)	
Alpha	99.23(9)		{99.46(10)**	
			{99.19(11)	
"Weighted Average of all Runs	99.87(40)		99.53(50)	
Transfer Units, Nt	6.6		5.4	
Average pressure drop across sand filter, in. water	7.0		4.1	

* Values given in () after percentage collection efficiency values represent number of measurements used in average.

** In these cases one value which obviously was in error was omitted from the average.

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